United States Environmental Protection Agency
Office of Solid Waste and Emergency Response
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Guide for Conducting Treatability Studies under CERCLA: Soil Washing

Office of Emergency and Remedial Response
Hazardous Site Control Division OS-220

QUICK REFERENCE FACT SHEET

Section 121 (b) of CERCLA mandates that EPA should select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and that EPA should prefer remedial actions in which treatment that "permanently reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants is a principal element." Treatability studies provide data to support treatment technology selection and remedy implementation and should be performed as soon as it is evident that insufficient information is available to ensure the quality of the decision. Conducting treatability studies early in the remedial investigation/feasibility study (RI/FS) process should reduce uncertainties associated with selecting the remedy, and provide a sounder basis for the ROD. Regional planning should factor in the time and resources required for these studies.

This fact sheet provides a summary of information to facilitate the planning and execution of soil washing remedy selection treatability studies in support of the RI/FS and the remedial design/remedial action (RD/RA) processes. This fact sheet follows the organization of the "Guide for Conducting Treatability Studies Under CERCLA: Soil Washing," Interim Guidance, EPA/540/000/000A September 1991. Detailed information on designing and implementing remedy selection treatability studies for soil washing is provided in the guidance document.

INTRODUCTION

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. The "Guide for Conducting Treatability Studies Under CERCLA: Soil Washing Remedy Selection" discusses the remedy screening and remedy selection levels.

Remedy screening studies are designed to provide a quick and relatively inexpensive indication of whether soil washing is a potentially viable remedial technology. Soil washing remedy screening studies should not be the only level of testing performed before final remedy selection. Remedy selection and remedy design studies will also be required to determine if soil washing is a viable treatment alternative for a site. The remedy selection evaluation should provide an indication that reductions in contaminant concentrations or in the volume of contaminated soil will meet site-specific cleanup goals. It will also produce the design information required for the next level of testing. Remedy design studies may be needed to optimize process design.

TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

Technology Description

Soil washing is a physical/chemical separation technology in which excavated soil is pretreated to remove large objects and soil clods and then washed with fluids to remove contaminants. To be effective, soil washing must either transfer the contaminants to the wash fluids or concentrate the contaminants in a fraction of the original soil volume, using size separation techniques. In either case, soil washing must be used in conjunction with other treatment technologies. Either the washing fluid or the fraction of soil containing most of the contaminant, or both, must be treated.

At the present time, soil washing is used extensively in Europe and has had limited use in the United States. During 1986-1989, the technology was one of the selected source control remedies at eight Superfund sites.

The determination of the need for and the appropriate level of treatability studies required is dependent on the literature information available on the technology, expert technical judgment, and site-specific factors. Several reports and electronic data bases exist that should be consulted to assist in planning and conducting treatabilty studies as well as help prescreen soil washing for use at a specific site. Site-specific technical assistance is provided to Regional Project Managers (RPMs) and On-Scene Coordinators (OSCs) by the Technical Support Project (TSP).

Prescreening Characteristics

Prescreening activities for the soil washing treatability testing include interpreting any available site-related field measurement data. The purpose of prescreening is to gain enough information to eliminate from further treatability testing those treatment technologies which have little chance of achieving the cleanup goals.

The three most important soil parameters to be evaluated during prescreening and remedy screening tests are the grain size distribution, clay content, and cation exchange capacity. Soil washing performance is closely tied to these three factors. Soils with relatively large percentages of sand and gravel (coarse material >2 mm in particle size) respond better to soil washing than soils with small percentages of sand and gravel. Larger percentages of clay and silt (fine particles smaller than 0.25 mm) reduce soil washing contaminant removal efficiency. In general, soil washing is most appropriate for soils that contain at least 50 percent sand/gravel, i.e., coastal sandy soils and soils with glacial deposits. Soils rich in clay and silt tend to be poor candidates for soil washing. Cation exchange capacity measures the tendency of the soil to exchange weakly held cations In the soil for cations in the wash solution, which will be more strongly bound to the soil. Soils with relatively low CEC values (less than 50 to 100 meq/kg) respond better to soil washing than soils with higher CEC values. Early characterization of these parameters and their variability throughout the site provides valuable information for the initial screening of soil washing as an alternative treatment technology.

Chemical and physical properties of the contaminant should also be investigated. Solubility in water (or other washing fluids) is one of the most important physical characteristics. Reactivity with wash fluids may, in some cases, be another important characteristic to consider. Other contaminant characteristics such as volatility and density may be important for the design of remedy screening studies and related residuals treatment systems. Speciation is important in metal-contaminated sites. Specific metal compounds should be quantified rather than total metal concentration for each metal present at the site.

There is no steadfast rule that specifies, when to proceed with remedy screening and when to eliminate soil washing as a treatment technology based on a preliminary screening analysis. A literature search indicating that soil washing may not work at a given site should not automatically eliminate soil washing from consideration. On the other hand, previous studies indicating that pure chemicals will be effectively treated using soil washing must be viewed with caution. Chemical interactions in complex mixtures frequently found at Superfund sites or interactions between soil and contaminants can limit the effectiveness of soil washing. An analysis of the existing literature, coupled with the site characterization, will provide the information required to make an "educated decision." However, when in doubt, a remedy screening study is recommended.

Technology Limitations

Many factors affect the feasibility of soil washing. These factors should be addressed prior to the selection of soil washing, and prior to the investment of time and funds in further testing. A detailed discussion of these factors is beyond the scope of this document.

THE USE OF TREATABILITY STUDIES IN REMEDY SELECTION

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support the remedy evaluation and implementation process. A well-designed treatability study can significantly reduce the overall uncertainty associated with the decision but cannot guarantee that the chosen alternative will be completely successful. Care must be exercised to ensure that the treatability study is representative of the treatment as it will be employed (e.g., the sample is representative of the contaminated soil to be treated) to minimize the uncertainty in the decision. The method presented below provides a resource-effective means for evaluating one or more technologies.

There are three levels or tiers of treatability studies: remedy screening remedy selection and remedy design. Some or all of the levels may be needed on a case-by-case basis. The need for, and the level of, treatability testing required are management decisions in which the time and cost necessary to perform the testing are balanced against the risks inherent in the decision (e.g., selection of an inappropriate treatment alternative). Figure 1 shows the relationship of three levels of treatability study to each other and to the RI/FS process.

Remedy Screening

Remedy screening is the first level of testing. It is used to establish the ability of a technology to treat a waste. These studies are generally low cost (e.g., $10,000 to $50,000) and usually require hours to days to complete. The lowest level of quality control is required for remedy screening studies. They yield data enabling a qualitative assessment of a technology's potential to meet performance goals. Remedy screening tests can identify operating standards for investigation during remedy selection or remedy design testing. They generate little, if any, design or cost data, and should never be used as the sole basis for selection of a remedy.

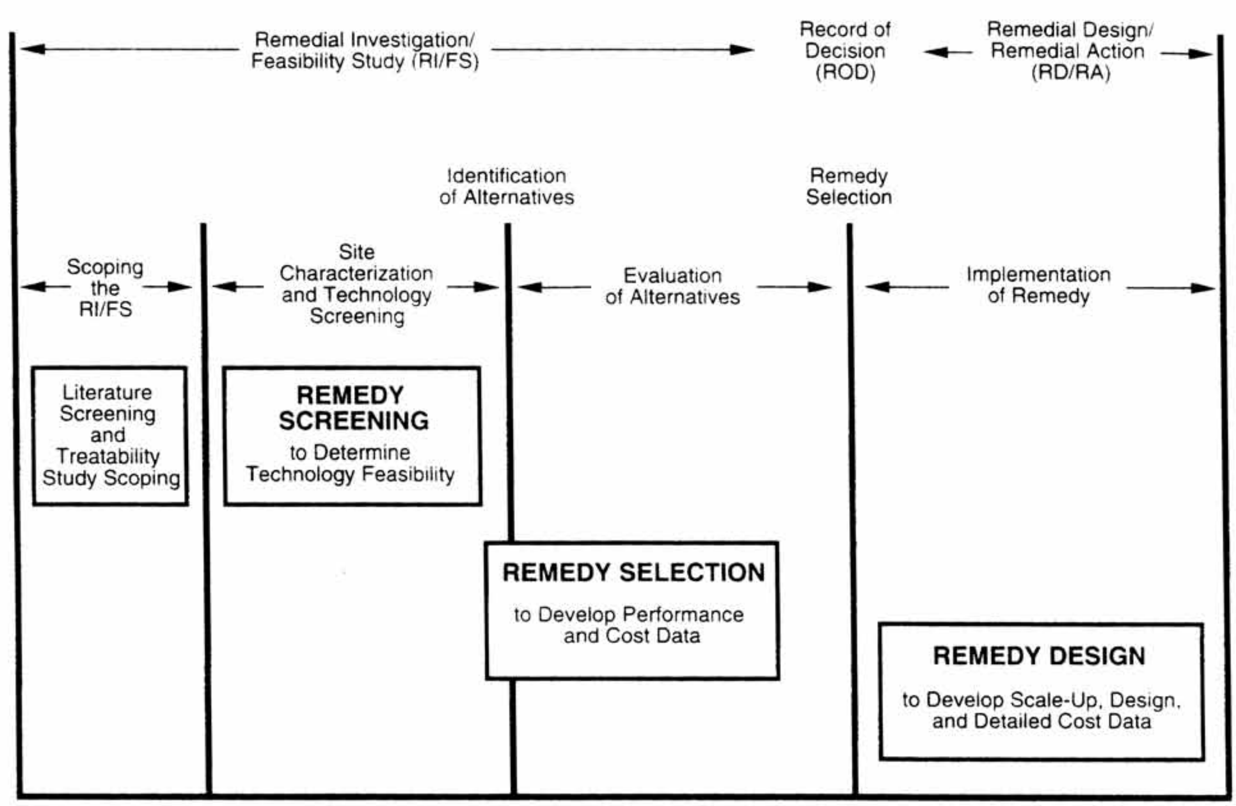

Figure 1. The Role of Ttreatability Studies in the RI/FS and RD/RA Process.

Remedy screening soil washing treatability studies are frequently skipped. Often, there is enough information about the physical and chemical characteristics of the soil and contaminant to allow an expert to evaluate the potential success of soil washing at a site. When performed, remedy screening tests are jar tests. However, remedy selection tests are normally the first level of treatability study executed.

Remedy Selection

Remedy selection testing is the second level of testing. Remedy selection tests identify the technology's performance for a site. These studies have a moderate cost (e.g., $20,000 to $100,000) and require several weeks to complete. Remedy selection tests yield data that verify that the technology can meet expected cleanup goals, provide information in support of the detailed analysis of alternatives (i.e., seven of the nine evaluation criteria), and give indications of optimal operating conditions.

The remedy selection tier of soil washing testing generally consists of laboratory tests which provide sufficient experimental controls such that a semi-quantitative mass balance can be achieved. Toxicity testing of the cleaned soil is typically employed in the remedy selection tier of treatability testing. The key question to be answered during remedy selection testing is how much of the soil will this process treat by either particle size separation or solubilization to meet the cleanup goal. The exact removal efficiency needed to meet the specified goal for the remedy selection test is site-specific. In some cases, pilot-scale testing may be appropriate to support the remedy evaluation of innovative technologies. Typically, a remedy design study would follow a successful remedy selection study.

Remedy Design

Remedy design testing is the third level of testing. It provides quantitative performance, cost, and design information for remediating an operable unit. This testing also produces remaining data required to optimize performance. These studies are of moderate to high cost (e.g., $100,000 to $500,000) and require several months to complete. For complex sites (e.g., sites with different types or concentrations of contaminants in different areas or with different soil types in different areas), longer testing periods may be required, and costs will be higher. Remedy design tests yield data that verify performance to a higher degree than the remedy selection and provide detailed design information. They are performed during the remedy implementation phase of a site cleanup.

Remedy design tests usually consist of bringing a mobile treatment unit onto the site, or constructing a small-scale unit for nonmobile technologies. Permit exclusions may be available for offsite treatability studies under certain conditions. The goal of this tier of testing is to confirm the cleanup levels and treatment times specified in the Work Plan. This is best achieved by operating a field unit under conditions similar to those expected in the full-scale remediation project.

Data obtained from the remedy design tests are used to:

- Design the full-scale unit
- Confirm the feasibility of soil washing based on target cleanup goals
- Refine cleanup time estimates
- Refine cost predictions.

Given the lack of full-scale experience with innovative technologies, remedy design testing will generally be necessary in support of remedy implementation.

REMEDY SELECTION TREATABILITY STUDY WORK PLAN

Carefully planned treatability studies are necessary to ensure that the data generated are useful for evaluating the validity or performance of a technology, The Work Plan, which is prepared by the contractor when the Work Assignment is in place, sets forth the contractor's proposed technical approach for completing the tasks outlined in the Work Assignment. It also assigns responsibilities and establishes the project schedule and costs. The Work Plan must be approved by the RPM before initiating subsequent tasks. A suggested organization of the Work Plan is provided in the "Guide for Conducting Treatability Studies Under CERCLA Soil Washing."

Test Goals

Setting goals for the treatability study is critical to the ultimate usefulness of the data generated. Goals must be defined before the treatability study is performed. Each tier of treatability study needs performance goals appropriate to that tier.

Remedy screening tests are not always performed for soil washing processes. If remedy screening tests are performed, an example of the goal for those tests would be to show that the wash fluid will solubilize or remove a sufficient percentage (e.g., 50 percent) of the contaminants to warrant further treatability studies. Another goal might be to show that contaminant concentrations can be reduced in the >2 mm soil fraction by at least 50 percent, as compared to the original soil concentrations, using particle size separation techniques. These goals are only examples. The remedy screening treatabilty study goals must be determined on a site-specific basis.

Achieving the goals during this tier should merely indicate that soil washing has at least a limited chance of success and that further studies will be useful. Frequently, such information is available based on the type of soil and contaminant present at the site. Based on such information, experts in soil washing technology can often assess the potential applicability of soil washing without performing remedy screening.

The main objectives of the remedy selection tier of testing are to:

- Measure the percentage of the contaminant that can be removed from the soil through solubilization or from the >2 mm soil fraction by particle size separation.
- Produce the design information required for the next level of testing, should the remedy selection evaluation indicate remedy design studies are warranted.
- The actual goal for removal efficiency must be based on site- and process-specific characteristics. The specified removal efficiency must meet site cleanup goals, which are based on a site risk assessment or on the applicable or relevant and appropriate requirements (ARARs).

Experimental Design

A jar test is the type of remedy screening test that can be rapidly performed in an onsite laboratory to evaluate the potential performance of soil washing as an alternative technology. Such studies should be designated to maximize the chances of success at the remedy screening level. The object of this guidance document is not to specify a particular remedy screening method but rather to highlight those critical parameters which should be evaluated during the laboratory test.

Contaminant characteristics to examine during remedy screening include solubility, miscibility, and dispersibility. Properties of organic contaminants are generally easier to evaluate than those of inorganic contaminants. Inorganics, such as heavy metals, can exist in many compounds (e.g., oxides, hydroxides, nitrates, phosphates, chlorides, sulfates, and other more complex mineralized forms), which can greatly alter their solubilities. Metal analyses typically provide only total metal concentrations, More detailed analyses to determine chemical speciation may be warranted.

The liquid used in the jar test is typically water, or water with additives which might enhance the effectiveness of the soil washing process. To save time and money, chemical analyses should not be performed on the samples until there is visual evidence that physical separation has taken place in the jar tests. Jar tests can yield three separate fractions from the original soil sample. These include a floating layer, a wastewater with dispersed solids, and a solid fraction. Chemical analysis can be performed on each fraction.

When performing the jar test, observe if any floating materials can be skimmed off the top. Observe whether an immiscible, oily layer forms, either at the top or the bottom, indicating release of an insoluble organic material. Observe and time the solids settling rate and depth. Sand and gravel settle first, followed by the silt and clay. The rate and the relative volume of the settling material will provide some indication of the particle size distribution in the waste matrix and the potential for soil washing as a treatment alternative. Further evidence can be gained by analyzing the settled and filtered wash water for selected indicator contaminants of concern. If simple washing releases a large percentage of these contaminants into the wash water, then soil washing can be viewed favorably and more detailed laboratory and bench tests must be conducted.

Variations on the jar tests can include the addition of surfactants, chelants, or other dispersant agents to the water; sequential washing; heated water washing versus cold water; acidic or basic wash water; and tests that include both a wash and a rinse step. The rinse water and fine soil fraction (<2 mm particle size) should be separated from the coarse soil fraction (>2 mm particle size) using a #10 sieve. No attempt should be made during jar tests to separate the soil into discrete size fractions; this is done at the bench-scale tier of testing. Normally, only the coarse soil fraction should be analyzed for contamination. In general, at least a 50 percent reduction in total contaminant concentration in the >2 mm soil fraction is considered adequate to proceed to the remedy selection tier. The separation of approximately 50 percent of the total soil volume as clean soil also indicates remedy selection studies may be warranted.

To reduce analytical costs during the remedy screening tier, a condensed list of known contaminants must be selected as indicators of performance. The selection of indicator analytes to track during jar testing should be based on the following guidelines:

- Select one or two contaminants present in the soil that are most toxic or most prevalent.
- Select indicator compounds to represent other chemical groups if they are present in the soil (i.e., volatile and semivolatile organics, chlorinated and nonchlorinated species, etc.)
- If polychlorinated biphenyls (PCBs) and dioxins are known to be present, select PCBs as indicators in the jar tests and analyze for them in the washed soil. It is usually not cost-effective to analyze for dioxins and other highly insoluble chemicals in the wash water generated from jar tests. Check for them later in the wash water from remedy selection tests.

Remedy selection tests require that electricity, water, and additional equipment are available. The tests are run under more controlled conditions than the jar tests. The response of the soil sample to variable washing conditions is fully characterized. More precision is used in weighing, mixing, and particle size separation. There is an associated increase in QA/QC costs. Treated soil particles are separated during the sieve operations to determine contaminant partitioning with particle size. Chemical analyses are performed on the sieved soil particles as well as on the spent wash waters. The impact of process variables on washing effectiveness is quantified. This series of tests is considerably more costly than jar tests, so only samples showing promise in the remedy screening phase (jar test) should be carried forward into the remedy selection tier. If sufficient data are available in the prescreening step, the remedy screening step may be skipped. Soil samples showing promise in the prescreening step are carried forward to the remedy selection tier.

A series of tests should be designed that will provide information on washing and rinsing conditions best suited to the soil matrix under study. The RREL data base should be searched for information from previous studies. To establish percent of contaminant removal, particle size separation, and distribution of contaminants in the washed soil, the following should first be studied: 1) wash time, 2) wash water-to-soil ratio, and 3) rinse water-to-wash water ratio. Following those studies, the effect of wash water additives on performance should be evaluated.

Several factors must be considered in the design of soil washing treatability studies. A remedy selection test design should be geared to the type of system expected to be used in the field. Soil-to-wash water ratios should be planned using the results from the jar tests, if jar tests were performed. In general, a ratio of 1 part of soil to 3 parts of wash water will be sufficient to perform remedy selection tests. The soil and wash water should be mixed on a shaker table for a minimum of 10 minutes and a maximum of 30 minutes. The soil-to-wash water ratio and mix times presented here are rules of thumb to be used if no other information is available.

Another factor to consider is the variability of the grain size distribution. Gilsen Wet Sieve devices are recommended for remedy selection studies. Ro-Tap or similar sieve systems may also be used. Such devices will enhance the completeness and reproducibility of grain size separation. However, they are messy, expensive, and very noisy when in operation. An alternate choice is to complete a series of four to six replicate runs under exactly the same set of conditions to obtain information on the variability of the grain size separation technique. Variability in the separation technique can be evaluated by comparing sieve screen weights across runs and soil contaminant data for the same fractions from each run. By identifying the range of variability associated with repeated runs at the same conditions, estimates can be made of the variability that is likely to be associated with other test runs under slightly different conditions.

Normally, only the wash water and the soil particles captured by the sieve screen need to be analyzed for contaminants. Experience has shown that little additional contaminant removal is likely to be found in the rinse water. Rinsing is important and must be included in the procedure since it improves the efficiency of the grain size separation/sieving process. Rinsing separates the fine from the coarse material. This can result in a cleaner coarse fraction and more contaminant concentrated in the fine fraction. Contaminant concentration in the rinse water may be determined periodically (e.g., 10 percent of the samples) to evaluate the performance of the wash solution. However, very little contamination is typically dissolved in the rinse solution. Therefore, analyses of the rinse solution may have limited value in verifying wash solution performance.

Initially, only the coarse soil fraction and the wash water should be analyzed for indicator contaminants. If the removal of the indicator contaminants confirms that the technology has the potential to meet cleanup standards at the site, additional analyses should be performed. All three soil fractions and all wash and rinse waters must be analyzed for all contaminants to perform a complete mass balance. The holding time of soil fractions in the lab before extraction and analysis can be an important consideration for some contaminants.

The decision on whether to perform remedy selection testing on hot spots or composite soil samples is difficult and must be made on a site-by-site basis. Hot spot areas should be factored into the test plan if they represent a significant portion of the waste site. However, it is more practical to test the specific waste matrix that will be fed to the full-scale system over the bulk of its operating life. If the character of the soil changes radically (e.g., from day to sand) over the depth of contamination, then tests should be designed to separately study system performance on each soil type.

Additives such as oil and grease dispersants and chelating agents can aid in removing contaminants from some soils. However, they can also cause processing problems downstream from the washing step. Therefore, use of such additives should be approached with caution. Use of one or a combination of those additives is a site-by-site determination. Some soils do not respond well to additives. Surfactants and chelating agents may form suspensions and foams with soil particles during washing. This can clog the sieves and lead to inefficient particle size separation during screening. The result can be the recovery of soil fractions with higher contamination than those cleaned by water alone. Such results can make the data impossible to understand. Additives can also complicate the rinse water process that might follow the soil washing. Recent studies have shown that counter-current washing-rinsing systems, incorporating the use of hot water for the initial wash step, offer the best performance in terms of particle size separation, contaminant removal, and wastewater management (treatment, recycling and discharge).

SAMPLING AND ANALYSIS PLAN

The Sampling and Analysis Plan (SAP) consists of two parts–the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPjP). A SAP is required for all field activities conducted during the RI/FS. The purpose of the SAP is to ensure that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit. The SAP is usually prepared after Work Plan approval.

Field Sampling Plan

The FSP component of the SAP describes the sampling objectives; the type, location, and number of samples to be collected; the sample numbering system; the necessary equipment and procedures for collecting the samples; the sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

Field samples are taken to provide baseline contaminant concentrations and material for the treatability studies. The sampling objectives must be consistent with the treatability test objectives. Because the primary objective of remedy screening studies is to provide a first-cut evaluation of the extent to which specific chemicals are removed from the soil or concentrated in a fraction of the soil by soil washing, the primary sampling objectives should include, in general:

- Acquisition of samples representative of conditions typical of the entire site or defined areas within the site. Because this is a first-cut evaluation, elaborate statistically designed field sampling plans may not be required. Professional judgment regarding the sampling locations should be exercised to select sampling sites that are typical of the area (pit, lagoon, etc.) or appear above the average concentration of contaminants in the area being considered for the treatability test. This may be difficult because reliable site characterization data may not be available early in the remedial investigation.

- Acquisition of sufficient sample volumes necessary for testing, analysis, and quality assurance and quality control.

The sampling plan for remedy selection will be similar. However, because a mass balance is required for this evaluation, a statistically designed field sampling plan will be required.

Quality Assurance Project Plan

The Quality Assurance Project Plan should be consistent with the overall objectives of the treatability study. At the remedy screening level the QAPjP should not be overly detailed.

The purpose of the remedy selection treatability study is to determine whether soil washing can meet cleanup goals and provide information to support the detailed analysis of alternatives (i.e., seven of the nine evaluation criteria). An example of a criterion for this determination is removal of approximately 90 percent of contaminants. The exact removal efficiency specified as the goal for the remedy selection test is site-specific. The suggested QC approach will consist of:

- Triplicate samples of both reactor and controls

- The analysis of surrogate spike compounds in each sample

- The extraction and analysis of a method blank with each set of samples

- The analysis of a matrix spike in approximately 10 percent of the samples.

The analysis of triplicate samples provides for the overall precision measurements that are necessary to determine whether the difference is significant at the chosen confidence level. The analysis of the surrogate spike will determine if the analytical method performance is consistent (relatively accurate). The method blank will show if laboratory contamination has had an impact on the analytical results.

Selection of appropriate surrogate compounds will depend on the target compounds identified in the soil and the analytical methods selected for the analysis.

TREATABILITY DATA INTERPRETATION

The information and results gathered from the remedy screening are used to determine if soil washing is a viable treatment option and to determine if additional remedy selection and remedy design studies are warranted. A reduction of approximately 50 percent of the soil contaminants during the test indicates additional treatability studies are warranted. Contaminant concentrations can also be determined for wash water and fine soil fractions. These additional analyses add to the cost of the treatability test and may not be needed. Before and after concentrations can normally be based on duplicate samples at each period. The mean values are compared to assess the success of the study. If the remedy screening indicates that soil washing is a potential cleanup option then remedy selection studies should be performed.

In remedy selection treatability studies, soil contaminant concentrations before soil washing and contaminant concentrations in the coarse fraction after soil washing are typically measured in triplicate. A reduction of approximately 90 percent in the mean concentration indicates soil washing is potentially useful in site remediation. A number of other factors must be evaluated before deciding to proceed to remedy design studies.

The final concentration of contaminants in the recovered (clean) soil fraction, in the fine soil fraction and wastewater treatment sludge, and in the wash water are important to evaluating the feasibility of soil washing. The selection of technologies to treat the fine soil and wash water wastestreams depends upon the types and concentrations of contaminants present. The amount of volume reduction achieved is also important to the selection of soil washing as a potential remediation technology.

TECHNICAL ASSISTANCE

Literature information and consultation with experts are critical factors in determining the need for and ensuring the usefulness of treatability studies. A reference list of sources on treatability studies is provided in the "Guide for Conducting Treatability Studies Under CERCLA" (EPA/540/2-89/058).

It is recommended that a Technical Advisory Committee (TAC) be used. This committee includes experts on the technology who provide technical support from the scoping phase of the treatability study through data evaluation. Members of the TAC may include representatives from EPA (Region and/or ORD), other Federal Agencies, States, and consulting firms.

OSWER/ORD operate the Technical Support Project (TSP) which provides assistance in the planning, performance, and/or review of treatability studies. For further information on treatability study support or the TSP, please contact:

Groundwater Fate and Transport Technical Support Center
Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, OK
Contact: Don Draper
FTS 743-2200 or (405) 332-8800

Engineering Technical Support Center
Risk Reduction Engineering Laboratory (RREL), Cincinnati, OH
Contact: Ben Blaney
FTS 684-7406 or (513) 569-7406

FOR FURTHER INFORMATION

In addition to the contacts identified above, the appropriate Regional Coordinator for each Region located in the Hazardous Site Control Division/Office of Emergency and Remedial Response or the CERCLA Enforcement Division/Office of Waste Programs Enforcement should be contacted for additional information or assistance.

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